SCIENTIFIC OBJECTIVES

Introduction

In identifying those problems which are best addressed by an orbiting lidar system, the special features of the lidar must be considered. These features are

(1) The ability to actively probe the atmosphere

(2) Very good vertical resolution when used in the pulsed mode

(3) Fine horizontal resolution with the capability to probe the troposphere between the clouds

(4) Very high sensitivity in aerosol and thin-cloud detection

(5) The ability to select atmospheric constituents by narrow spectral features, such as in resonant scatter or in absorption

(6) The ability to measure temperatures of these constituents by the spectral shape of the features, given adequate spectral purity of the laser

(7) The possibility of measuring the spectrum of the lidar return either by high-resolution interferometry or by heterodyne detection, with sufficient resolution to determine the Doppler shift; thence, after eliminating the satellite motion, to deduce the atmospheric motion field

(8) The ability to obtain global-scale data rapidly

(9) The ability to point the lidar system in any direction, subject to the restriction of slew rate and scattered sunlight

The scientific objectives presented in this section, while of great interest and significance themselves, are not the entire range of scientific problems of interest in the atmosphere. Rather, they are a set of very important problems to which the orbiting lidar can make a unique contribution - problems that cannot be solved by other techniques alone. Some of them can be addressed by lidar itself without any accompanying observations; in other cases, complementary observations by passive techniques, in situ probes from balloons or rockets, or radio probing from the ground are needed to obtain the maximum scientific benefit. These correlative observations are indicated for each objective.

As a consequence of special features (2) and (3) given above, an orbiting lidar will have a view of the troposphere that is unique among spaceborne sensors. That is, although passive limb scanners can have quite good vertical resolution, their view of the troposphere is usually blocked by clouds; on the other hand, passive nadir viewing sensors, which can view between the clouds, have less vertical resolution and often less sensitivity. Lidar's unmatched

ability to probe between clouds with good vertical resolution opens up a whole class of global tropospheric studies that only spaceborne experiments can provide. Examples of these studies are mentioned below and elaborated on in later sections.

It also happens that the capabilities of orbiting lidar make it particularly suitable for studies of the stratosphere and mesosphere. This region, between 10 and 100 km altitude, is known as the "middle atmosphere." The scientific problems for this region were studied at a 1976 conference in Urbana, Illinois, and are documented in the Middle Atmosphere Program Planning Document (1976). Further discussions of the problems are contained in the Upper Atmosphere Research Satellite planning document (1978) and in "Upper Atmosphere Research in the 1980's - Ground-Based Rocket and Airborne Techniques," a document in preparation by the Committee on Solar Terrestrial Research, National Academy of Sciences - National Research Council, Washington, DC 20418.

As a result of strong international scientific interest, the Middle Atmosphere Program (MAP) has been approved by the International Council of Scientific Unions as a program of cooperative research in the period 1982-1985, with the participation of four scientific unions, the Scientific Committees on Space Research and on Solar-Terrestrial Physics, and the World Meteorological Organization.

One of the questions of prime scientific concern in the middle atmosphere is the mechanism by which long-lived chemical compounds and particulates make their way from the Earth's surface into the middle atmosphere. Simplified one- or two-dimensional models parameterize this flow in terms of an eddy transport coefficient. However, the situation in the real atmosphere is much more complex. Not only are the sources unevenly distributed over the surface of the globe, but the vertical transport is dominated by troposphere/stratosphere exchange like that found in the tropics and that associated with tropopause folding at medium latitudes. Scientific objective 1 addresses itself to the problem of tracing the actual paths followed by various tracers and relating it to the general circulation. If the Spacelab lidar is operational during the period of MAP from 1982 to 1985, it will be able to make a substantial contribution to this international cooperative effort.

The global distribution of natural and artificial minor constituents in the middle atmosphere is of great importance in determining the chemistry of ozone. The Spacelab lidar will be capable of measuring ozone and other related chemical species and can make a substantial contribution to the knowledge of ozone chemistry. As described under scientific objective 2, the scientific yield from the lidar measurements will be greatly enhanced by combining them with passive measurements from space, balloon, and rocket measurements of minor constituent concentrations.

All models of the terrestrial climate involve assumptions about radiative parameters of the atmosphere. Since a lidar system is capable of measuring a wide range of radiatively active constituents with precision in altitude, it can provide a new data base for global radiative models, as described in scientific objective 3. In fact, since the largest amounts of radiatively active constituents (e.g., aerosols, water vapor, CO_2) are located in the troposphere,

lidar's unique view of this atmospheric layer (mentioned above) is especially applicable to this objective. As an example, the unique ability of Shuttle lidar to make global measurements of tropospheric aerosols with the required vertical resolution and sensitivity has been cited in the planning document, "Guidelines for the Aerosol Climatic Effects Special Study: An Element of the NASA Climate Research Program" (1979).

The Global Atmospheric Research Program (GARP), which is intended to provide data to test new global circulation models of the atmosphere, can benefit from certain limited but important measurements of temperature, pressure, and cloud-top height which will be derived from the Spacelab lidar program. The benefits and limitations of these data are explored under scientific objective 4.

Scientific objectives 5, 6, and 7 relate to a number of problems in the atmosphere above the stratosphere accessible to neither balloons nor satellites. In this region, scatter from aerosols is much less frequent and Rayleigh scatter by air molecules is too weak for use by lidar. However, a number of species are present which can scatter resonantly, for example, atmospheric metals, metal ions, and hydroxyl. These will be used as tracers to study thermospheric dynamics (objective 5), chemistry (objective 6), and electrodynamic coupling to the solar-terrestrial environment (objective 7). Together with ground-based optical and radar probing and the use of rockets where appropriate, lidar is expected to give a new perspective on the physics and chemistry of this interesting and complex part of the atmosphere.

References

Middle Atmosphere Program Planning Document. Dep. Elect. Eng., Univ. Illinois, June 1976.

Upper Atmosphere Research Satellite Program - Final Report of the Science Working Group. JPL Publ. 78-54, NAS7-100, July 15, 1978. (Available as NASA CR-157558.)

Guidelines for the Aerosol Climatic Effects Special Study: An Element of the NASA Climate Research Program. NASA TM-78554, 1979.